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The relationship of fire and soil type to floristic patterns within heathland vegetation near Badgingarra, Western Australia

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Abstract

Land management in the heath vegetation near Badgingarra, Western Australia, must involve a controlled burning regime which insures sufficient winter-flowering shrub communities for apicultural needs while providing protection of life and property for the adjacent agricultural and pastoral farmland. This study documents the major vegetation and habitat patterns in the region.

Species cover data were recorded from eight permanent plots representative of major topographical features and fire history. Ordination by principal components analysis and a hierarchical polythetic agglomerative classification revealed that the major habitat variables determining the diverse floristic composition of the plots were soil depth and time-since-the-last fire. Implications of imposing a controlled burning regime on these highly diverse plant communities are considered.

Introduction

Coastal areas of south-west Western Australia are dominated by extensive stands of heath vegetation (Beard 1984). These heathlands are considered to be among the most species-rich vegetation communities of the world and are further characterized by high levels of species endemism (Lamont *et al.* 1984). Ecologically complex, the heathlands have apparently developed as a result of habitat continuity over a long geological period, regional isolation, prolific speciation and adaptive radiation of certain groups, and the recurrent stress of a transitional climatic zone (Hopper 1979).

Although some of these heathlands are being preserved in National Parks and Nature Reserves, extensive areas have been cleared for agricultural, pastoral and mining land uses. The remaining native plant communities serve a number of economic purposes including tourism, the wildflower seed industry, the cut-flower trade and, in the northern regions (Fig. 1), as winter-season "honey bee pastures". The apicultural industry utilizes these plant communities, and especially the pollen they produce, to build bee numbers and hive vigour in anticipation of the spring and summer honey production seasons in the *Eucalyptus diversicolor, E. calophylla* and *E. marginata* dominated forests in the lower south-west of the state.

Amongst apiarists it is commonly believed that extended periods of many years free from fire are required for heath vegetation to achieve maximum pollen and nectar production. This need for fire protection is therefore, in apparent conflict with the far more frequent burning regime desired by agriculturalists and pastoralists for protection against wildfires which start in the native vegetation and spread into developed land. The Western Australian Bush Fires Board is charged with the management of non-vested vacant Crown land and with the establishment of a land management plan incorporating a fuel reduction burning regime to rationalize these, apparently, conflicting requirements.

Effective multiple-land use management requires both detailed knowledge of the biology of individual species and functional aspects of community ecology. Relevant information for the northern heath vegetation is however, presently limited. The objectives of the research described here were exploratory in nature and included (1) the establishment of a collection and listing of the flora from a small area within the region, (2) a determination of the relationships between plant species and specific soil types and (3) establishing whether differences in species composition could be documented for sites where the date of the most recent fire was known.

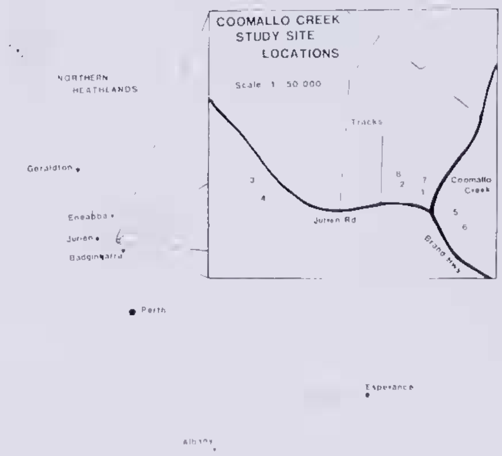

Figure 1.—Study site location in the northern heathlands of Western Australia between Badgingarra and Jurien.

Study Area

The major study area was sited within the northern heath vegetation in the vicinity of Coomallo Creek and approximately 20 km north of Badgingarra at the junction of the Brand Highway and the Jurien Road (30° 13′S 115° 23′E) (Fig. 1). Badgingarra has a typical Mediterranean type climate with cool, wet winters and hot, dry summers. The average rainfall, recorded at the Badgingarra Agriculture Research Station, is 633 mm with June having the highest monthly total. February is the warmest month with a mean monthly maximum of 34.8°C, and August is the coolest with a mean monthly minimum of 6.3°C. Geologically, the area is part of the Arrowsmith Region which comprises remnant laterized strata of Mesozoic age subsequently dissected by drainage channels (Lowry 1974). The present topography consists of lateritic plateau crests with gently sloping valley margins and sandy swales between the ridges. The colluvial slope and valley material is of local origin derived largely from the original laterites (Mulcahy 1973). The soils of the region are similar to those described immediately to the east of Badgingarra (Churchward 1970), predominantly a mosaic of yellow sands with ironstone and lateritic gravels outcropping on the ridges and appearing at varying depths below the sand on the valley sides. In the swales when associated with a watercourse the soils can be high in clay content.

The natural vegetation of the upper slopes and duricrust outcrops of the study area consists of low shrubs, 0.5-1.0 m in height, with scattered emergent individuals of *Xanthorrhoea reflexa* and *Kingia australis* (Beard 1979). Dense stands of *Hakea* spp., *Banksia* spp., *Adenanthos cygnorum* and *Jacksonia floribunda* attaining height of 2 to 3 m occur on the deep sands. Woodlands of *Eucalyptus wandoo* and *E. accedens* occur along the larger watercourses.

Several fires have burned through the study area in the recent past leaving patches of vegetation of varying age-since-last-burn.

Methods

Selection of Study Sites

Eight permanently marked study sites were established in the mosaic of soil and fire history types (Fig. 1):

Site 1. (Plots 1-5). Midslope, deep, yellowish sand burnt 9 years previously; located 220 m NW of the junction of the Brand Highway and Jurien Road.

Site 2. (Plots 6-10). Upper slope, laterite outcrop burnt 9 years, previously; located 1 km W of Site 1.

Site 3. (Plots 11-15). Upper slope, deep, yellowish sand burnt 2.5 years previously; located approx. 4 km WSW of Site 2.

Site 4. (Plots 16-20). Upper slope, laterite outcrop burnt 2.5 years previously; located 200 m SE of Site 3.

Site 5. (Plots 21-25). Midslope, deep, yellowish sand burnt 1.5 years previously; located 100 m E of the Coomallo Creek Campground.

Site 6. (Plots 26-30). Midslope, laterite outcrop burnt 1.5 years previously; located 200 m SE of Site 5.

Site 7. (Plots 31-35). Midslope, deep, yellowish sand burnt 10 years previously; located 100 m N of Site 1.

Site 8. (Plots 36-40). Upper slope, laterite outcrop burnt 10 years previously; located 100 m ENE of Site 2.

Although chosen to be represented of the more common plant communities in the area, the study sites represent a very small percentage of the geographic coverage of the vegetation types. The sites were generally believed to lie on a gradient of topographically related soil depths ranging between the very shallow sands over laterite of the old plateau surfaces to the deeper sands of the midslopes. Samples of this soil depth range included sites known from W.A. Bush Fires Board records to have been last burnt 1.5, 2.5, 9, and 10 years ago. For discussion purposes, sites burnt <3 years previously are designated to 'burnt', those >8 years as 'unburnt'.

Data Collection

Initial reconnaissance of the site involved collection of both vegetative and flowering material of the plants of the region. Subsequent identification revealed a total 212 recognizable taxa. Specimens are held in the herbarium of the Department of Botany, University of Western Australia. Nomenclature follows Green (1981).

Within each study site, five rectangular plots consisting of 10 contiguous replicate 1 m^2 quadrats were established at 5 m intervals. This sampling area of 50 m^2 per site based on spaced plots was regarded as appropriate to the preliminary nature of the investigation. The species within each quadrat were identified and cover values for each species recorded. Average cover per m^2 for each plot was determined and resulting data were key punched for storage and statistical manipulation on the Western Australia Regional Computing Centre's CDC-CYBER 170-720 computer.

Sites 1-4 were sampled in October 1979 and Sites 5-8 in October 1980.

Data Analysis

Due to computer storage limitations, the floristic data matrix was reduced to the 60 highest 'eident values' species by means of the matrix reduction system of Dale and Williams (1978). Analyses included both ordination and classification procedures.

Ordination was by centred and non-centred principal components analysis (PCA) utilizing the ORDIFLEX package of Gauch (1977). Separate computer runs for each form of PCA were performed in which species were, respectively, represented by presence/absence values and their cover values. The relative success with which centred and non-centred PCA may identify patterns amongst species associations is influenced by the number and complexity of discontinuities in the species distributions (Noy-Meir 1973). In this instance because the patterns were similar only those for the centred (presence/absence data) PCA are considered further.

Classification involved the hierarchical polythetic agglomerative procedures based on minimum dispersion (MDISP) and mutual information (MINFO) programmes of Orloci (1967, 1969). The data used were the species cover values. The results of the MINFO classification have been chosen for presentation as both algorithms produced similar patterns.

Results

A total of 212 taxa (γ-diversity) were recorded in the vicinity of the eight sites with 162 of these occurring at least once within the 40 sampled plots (Appendix 1). The general floristic richness of the region is indicated by the distribution of the taxa among families, genera and species (Table 1).

Table 1

Distribution of taxa within the study region.

	Families	Genera	Species
Gymnospermae	1	1	1
Monocotyledonae	8	36	50
Dicotyledonae	28	73	161
Total	37	110	212

Major families from the Monocotyledonae included Haemodoraceae (6 genera, 10 species), Lilaceae (6 genera, 7 species) and Restionaceae (7 genera, 9 species) while Epacridaceae (5 genera, 13 species), Leguminosae subfamily Papilionoideae (11 genera, 23 species), Myrtaceae (13 genera, 24 species) and Proteaceae (11 genera, 39 species) were predominant in the Dicotyledonae.

Given the relatively small plot area (50 m²) examined at each site, species richness levels were high and α- diversity varied between 90 (Site 4) and 62 (Site 5). Average species richness levels for the individual plots were around half the appropriate site value (Table 2). An ANOVA of the species richness values across the eight sites showed no significant differences ($F_{7, 32} = 1.42$; $0.3 > p > 0.2$).

Species occurrences ranged from single plants in single quadrats to *Hibbertia crassifolia* which occurred in 37 of the 40 plots. As many as 41 of the 162 encountered species exhibited some degree of restriction within the sand/laterite and burnt/unburnt environmental dichotomy (Table 3, Appendix 1). Given that the 'eident value' approach of Dale and Williams (1978) identifies those species contributing most to any patterning amongst species/plot occurrences, it could be expected that the 60 species selected for the analyses would include some *potentially* indifferent to either soil type or burning (generalists), those with preference for one or other soil types (edaphic indicators), and those responsive to the fire history of the plots (pyric indicators). Examination of the simplest of the PCA ordinations, that using species presence/absence data, would appear to confirm this assumption (Figs. 2 and 3).

Table 2

Levels of species richness amongst sampled plots and sites.

Site	Ecological Category: Edaphic	Ecological Category: Pyric	Overall Site Species Richness*	Mean number of species per plot	Range in species richness amongst plots
1	Sand	Burnt >8yrs	74	33.2	28 - 37
2	Laterite	Burnt >8yrs	79	36.0	26 - 42
3	Sand	Burnt <3yrs	71	35.6	31 - 42
4	Laterite	Burnt <3yrs	90	37.0	32 - 45
5	Sand	Burnt <3yrs	62	35.6	34 - 38
6	Laterite	Burnt <3yrs	72	32.0	29 - 36
7	Sand	Burnt >8yrs	72	36.4	33 - 41
8	Laterite	Burnt >8yrs	77	39.0	34 - 44

* Study Region: Average 74.6

Table 3

Distribution of species amongst ecological site categories.

Pyric[(a)] Distribution	Edaphic Distribution[(b)]: Sand	Non-edaphic specific	Laterite	Totals
Burnt < 3 yrs	13	5	13	31
Non-pyric specific	7	76[(c)]	24	107
Unburnt > 8 yrs	7	9	8	24
Totals	27	90	45	162

(a) Species restricted to either 'burnt' (<3 years) or 'unburnt' (>8 years) sites (pyric indicators)
(b) Species restricted to either sand or lateritic sites (edaphic indicators)
(c) Species with no evident site preferences, occurred in 3 of the 4 main ecological categories (generalists)

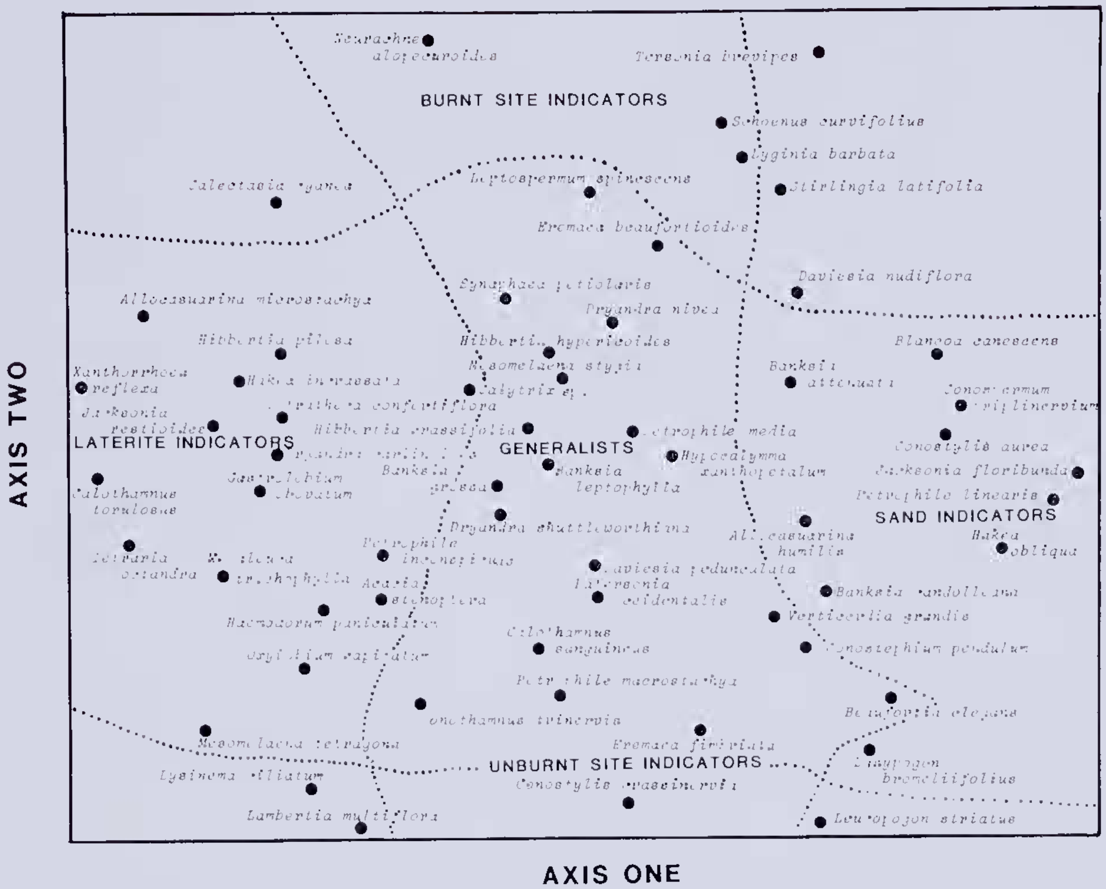

Figure 2.—Species ordination for centred PCA ordination on presence/absence data for the 60 highest eident value species. Soil type and fire category designation subjectively established from site preference data.

On the basis of their ecological distribution (Appendix 1), species can be segregated along the first axis into three subjective groups (Fig. 2). Species to the left end of the axis are those largely restricted to the laterite outcrop areas (e.g. *Xanthorrhoea reflexa, Calothamnus torulosus* and *Allocasuarina microstachya)*. In the central region are species found both on laterite and deep sand plots (e.g. *Hibbertia hypericoides, H. crassifolia* and *Dryandra shuttleworthiana*). Towards the right end of the axis are those species largely restricted to sand (e.g. *Hakea obliqua, Jacksonia floribunda* and *Petrophile linearis)*. The second axis differentiated in the upper half of the ordination those species occurring predominantly in recently burnt plots (e.g. *Tersonia brevipes* and *Neurachne alopecuroides)* and, in the lower portion, those species most often restricted to successionally older unburnt plots. Species restricted to sites in the deep sands where fires occurred more than 8 years prior to sampling included *Leucopogon striatus* and *Dasypogon bromeliifolius*. Species restricted to the unburnt laterite sites were *Lambertia multiflora* and *Lysinema ciliatum*. Other species with tendencies toward edaphic or fire history responses were subjectively categorised based on their location in the ordination space and the constancy of their presence in specific habitat types (see also Appendix 1).

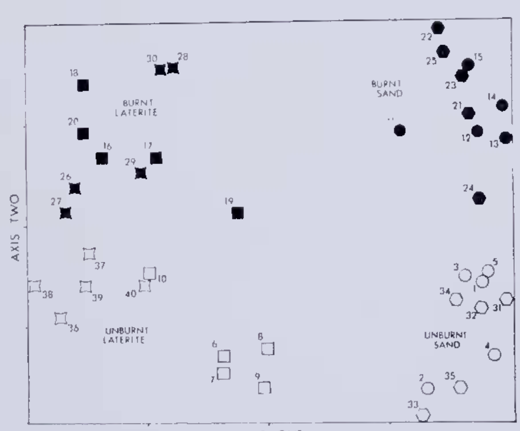

Figure 3.—Plot ordination for the centred PCA ordination on presence/absence data for the 60 highest eident value species. Location numbers appear for each of the 40 plots. Plots of each site appear as different symbols. The recently burnt sites are the darkened symbols; those more than 8 years since burnt appear as open symbols.

The combined effects of these edaphic and pyric indicator species resulted in a plot ordination which separated the sites according to their soil and fire date differences (Fig. 3). The separation of plots along the first PCA axis (accountable variance 23%) indicated that edaphic conditions were the most important parameters controlling community variation within the environmental domain sampled. The second axis (accountable variance 9%) showed a segregation of the burnt plots from the unburnt plots. Species responses to fire, therefore, appear also to be a factor in determining the composition of the habitats in the region. The absence of plot separation *within* the major fire history groups (i.e. between the 1.5 and 2.5 years-since-burnt plots or between the 9 and 10 years-since-last-burnt plots) is an indication that maturation of the communities following fire is gradual requiring several seasons for any changes in species composition to become obvious. The third PCA axis was found to be a reflection of the second axis and further axes (each with accountable variation <7%) could not be interpreted in ecological terms.

While the present levels of floristic variation attributable to the first two axes might seem meagre, interpretability of PCA ordination is not always simply related to accountable variation (Whittaker and Gauch 1973) and has not affected resolution in this study. Inclusion of quantitative cover data in the ordination made little difference to the overall interpretation. Those differences observed reflected the effects of a particular species present with locally high abundance (e.g. spreading shrubs such as *Banksia candolleana*). Most species had only low values when averaged across a plot and, therefore, were not greatly different from the 1's and 0's of presence/absence data.

Classification using the quantitative data supported the importance of edaphic variables as the major parameters defining the vegetation pattern (Fig. 4). The MINFO classification (as well as the MDISP classification) ultimately fused all plots from the deep sand areas into one group and the plots from the laterite outcrop areas into a second group.

Initial fusions amongst laterite sites grouped related plots from a single site, plot 10 (Site 2) being an exception but one in accord with its 'displaced' location within the ordination (Fig 3). Subsequent re-examination of the area has revealed the existence of laterite close to the surface in the vicinity of plot 10. This plot therefore, is more appropriately aligned with plots from Site 8 than its spatial location would otherwise suggest. Although the fire interval pattern is evident (mutual information level of 200), the fusion sequence indicates that Site 8 (unburnt) is more closely related to Sites 4 and 6 (burnt) than to Site 2 (unburnt).

Plot affiliations amongst the deep sand sites appear less precise than those for laterite, principally because of the diverse allocation of plots from Site 1 in the early stages of the agglomeration process. In this respect the classification and ordination results are most at variance. The difference would relate to the use of cover values by the classification and only presence/absence data in the ordination, for example, *Banksia candolleana* had very high cover in Sites 5 and 13 while *B. attenuata* was an important species in Sites 1, 14 and 15, being absent elsewhere. Apart from the inclusion of Sites 1 and 5 with the recently burnt group, the fire pattern of the sand sites is recovered by the classification in a consistent sequence.

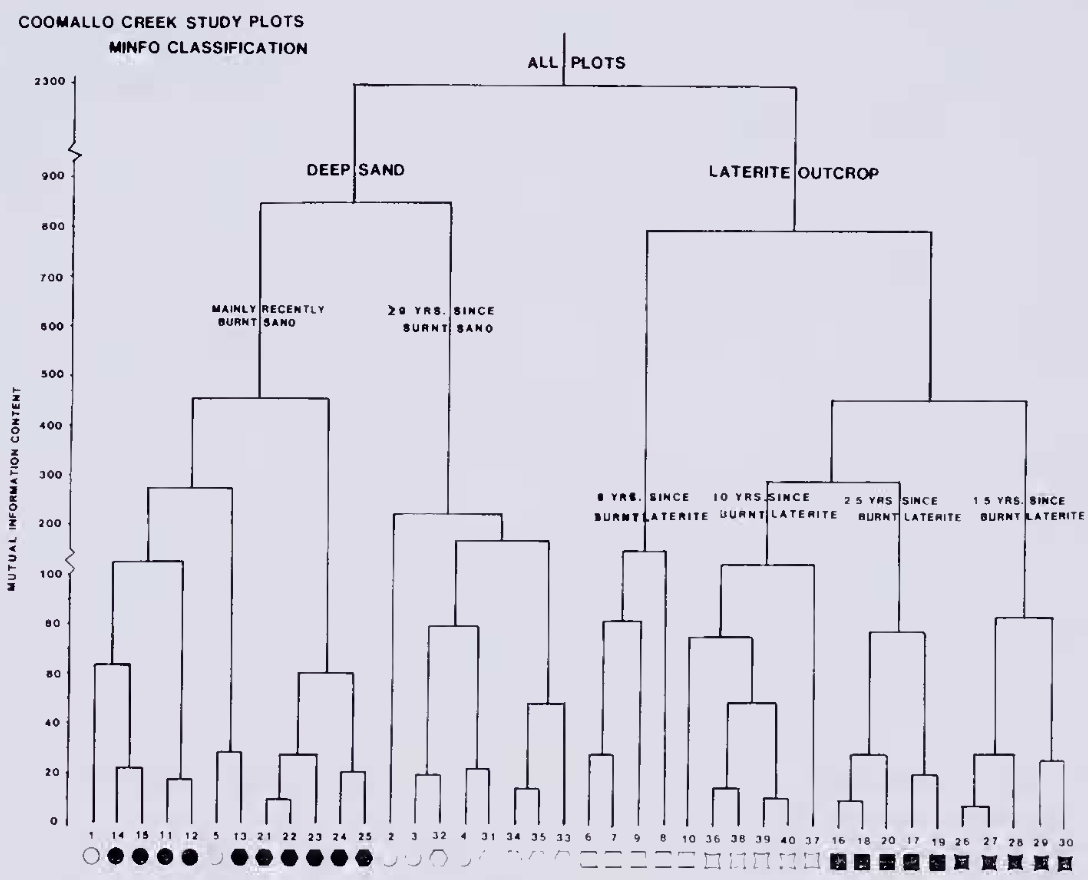

Figure 4.—Mutual Information Analysis (MINFO) plot classification of Badgingarra study area average cover value data. Location numbers and symbols appear as described on Figure 3.

Discussion

Because of the distribution of sites across a distance of some 6 km and the spacing of plots within sites, the effective area covered by this study was considerably larger than the overall quadrat area (400 m^2) actually examined would imply. The total of 212 species encountered and average site richness of 75 species/site represents levels of τ- and α-diversity respectively which are comparable with those reported from elsewhere in the northern heathlands (Table 4). As these figures also indicate, a larger plot size could be expected to result in a higher α-diversity while increased sampling intensity, inclusion of major drainage channel areas and seasonal collections would further increase γ-diversity. These levels of species richness highlight the botanical importance of the region and the need for more specific information of species behavioural patterns if future management is not to adversely affect the area's floristic composition.

Separation of the vegetation into areas represented by the laterite outcrops and the deep sandy sites is undoubtedly overemphasized by the choice of the site locations. Indeed, Hnatiuk and Hopkins (1981), who also found a similar division in areas away from winter-wet depressions in their Eneabba study, reported that although there were separate groups of species characterizing a lateritic soils unit and a deep sands unit, there was also a large degree of continuity between these two major units as nearly half of the species were found in both. The choice of study sites at the extremes of the topographically related soil depth gradient has perhaps maximised the polarization of species response patterns though even in this study, some 77 of the 162 species could be regarded as wide ranging.

Table 4

Summary of α- and γ-diversity levels for selected studies in northern heathland vegetation.

Location	Soils	α-diversity		γ-diversity		Reference
		Area (m^2)	Number of Species	Area (km^2)	Number of Species	
Eneabba Res. 31030	Sand over clay, deep sand, sand over laterite			6	239	A
Eneabba Res. 31030	Deep, white sand, Sand over laterite	50 500 50 500	65 77 71 92			B B
Eneabba Location 10413	Grey yellow sand or laterite	50 500	70 92			B
Eneabba	Clay, deep sand, laterite	1 000	91	20	429	C
Eneabba	Deep sand, laterite	16	54	ca 15	148	D
Mt. Lesueur Res. 15018	Clayey sand over laterite	50 500	60 67			B
Mt. Lesueur Res. 15018	Sand over laterite, laterite			0.5	286	E
Badgingarra Nat. Park 31809	Deep sand over laterite	50 500	59 71			B
Badgingarra-Coomallo Ck.	Deep sand, laterite	50	75	ca 6	212	F

A Lamont (1976)
B George *et al.* (1979)
C Hnatiuk and Hopkins (1981)
D Griffin and Hopkins (1981)
E Griffin and Hopkins (In press, cited in Lamont *et al.* 1984)
F Current study

The analysis of the floristic data by classification and ordination indicates that patterns related to the obvious geologic/edaphic features and most recent year of burning could be recovered. Additionally, these patterns were evident using either simple presence/absence records (in ordination) or species cover values (in classification). Given the nature of the expected patterns it must also be concluded that the 'eident value' reduction system has effectively reduced the large data set by maintaining the relative proportions of potential indicator species from the major ecological groups (Table 3).

While polarization of the sites into 'burnt' and 'unburnt' categories is similarly evident, the degrees to which this pattern is also indicative of site fire-history is more questionable. Records relating to fire intensity, seasonality, frequency and periodicity, those factors impinging upon the 'vital attributes' of species (*sensu* Noble and Slatyer 1979, 1981) and hence of importance in determining the pathway of post-fire succession, were unavailable. The slightly greater separation in the ordination between the burnt and unburnt sand sites when compared to the burnt and unburnt laterite sites may indicate that the sand regions are more affected by fires or that recovery from fire is more rapid in the laterite zones. A broader floristic survey is needed to substantiate the existence of any greater floristic dispersion between recently burned sites and sites older than 8 years on the deep sands than between sites on laterite.

Evidence is accumulating (see Baird 1977, Bell and Koch 1980, Bell *et al.* 1984) that many heathland species are either long-lived resprouters, (e.g. *Hibbertia hypericoides, Jacksonia floribunda)* or potentially long-lived seeders (e.g. *Hakea obliqua, Leucopogon striatus)* with relatively few species being short-lived perennials germinating from seed immediately following fire (e.g. *Tersonia brevipes*). Thus, a community should recover its original pre-fire composition and structure quickly and alter little over time. If the vegetation recovery pattern of these heathlands follows this initial floristic composition model (*sensu* Egler 1954), the pyric pattern identified here owes its origin to the floristic heterogeneity of the region as much as to any previous fire-history. Sites of known fire frequency etc. are required to establish this point.

Notwithstanding the exact source of the observed pyric pattern, if the fire frequency in managed heathlands is shorter than the time required by obligate seedling species to flower and successfully set seed, some species could be eliminated from a particular area. For example, the winter flowering species of *Leucopogon* are particularly favoured in apiculture (Smith 1969). If *L. striatus* proves to be an important species because of its pollen production, its apparent restriction to unburnt sites on deep sands could be a reason to restrict the burning of these habitats or increase the length of time between control burns. Elimination of a species by fire would not only be a potential loss to apiarists but also in an area which has a high degree of endemism, the loss could lead to eventual extinction. The enlightened use of fire in land management depends strongly on appropriate ecological information (Naveh 1974). Further data are required on the ecology of the species and communities in the Badgingarra region before a management policy incorporating all interests can be determined.

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Appendix 1

Coomallo Creek Study Area Species List. * denotes species not in transect sites. C denotes species used in computer analysis.

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
GYMNOSPERMAE					
Cupressaceae					
Actinostrobus acuminatus			+	+	
ANGIOSPERMAE					
MONOCOTYLEDONAE					
Cyperaceae					
Caustis dioica			+	+	
Lepidosperma sp.	+	+	+	+	
Mesomelaena stygia	+	+	+	+	C
Mesomelaena tetragona	+	+	+	+	C
Schoenus curvifolius	+		+	+	C
Schoenus sp.	+	+	+	+	
Tetraria octandra			+	+	C
Haemodoraceae					
Anigozanthos humilis	+	+	+		
Blancoa canescens	+	+		+	C
Conostylis aurea	+	+	+	+	C
Conostylis crassinervia		+		+	C
**Conostylis preissii*					
Conostylis teretifolia	+	+	+	+	
Haemodorum paniculatum	+	+	+	+	C
Haemodorum spicatum	+		+	+	
Macropidia fuliginosa			+	+	
**Phlebocarya ciliata*					
Iridaceae					
Patersonia occidentalis	+	+	+	+	C
Liliaceae					
Burchardia umbellata	+				
Johnsonia pubescens	+	+			
Laxmannia grandiflora	+		+		
Stawellia dimorphantha			+		
Thysanotus multiflora	+	+			
Thysanotus patersonii		+	+		
Tricoryne elatior			+		

Appendix 1—*continued*

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
Orchidaceae					
**Caladenia flava*					
**Caladenia gemmata*					
**Caladenia hirta*					
**Drakaea glyptodon*					
**Elythranthera brunonis*					
**Prasophyllum australe*					
**Thelymitra campanulata*					
Poaceae					
Amphipogon turbinatus	+				
Neurachne alopecuroides	+	+	+	+	C
Stipa variabilis	+				
Restionaceae					
Alexgeorgia sp.	+	+	+	+	
Ecdeiocolea monostachya	+	+	+	+	
Hypolaena sp.				+	
Loxocarya fasciculata			+		
Loxocarya sp.	+	+	+		
Lyginia barbata	+	+	+	+	C
Restio megalotheca			+		
Restio sphacelatus	+	+	+	+	
Xanthorrhoeaceae					
Calectasia cyanea	+		+	+	C
Dasypogon bromeliifolius	+	+			C
Lomandra hermaphrodita	+		+		
Lomandra sericea	+		+	+	
Lomandra sp. 1	+	+	+	+	
Lomandra sp. 2				+	
Xanthorrhoea reflexa	+	+	+	+	C
DICOTYLEDONAE					
Amaranthaceae					
**Ptilotus alopecuroides*					
Apiaceae					
Xanthosia huegelii	+	+		+	
Asteraceae					
**Angianthus tomentosus*					
**Podotheca gnaphalioides*					
Caesalpiniaceae					
Labichea punctata			+	+	

Appendix 1—*continued*

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
Casuarinaceae					
Allocasuarina humilis	+	+		+	C
Allocasuarina microstachya			+	+	C
Dicrastylidiaceae = (Verbenaceae)					
**Lachnostachys verbascifolia*					
Pityrodia bartlingii	+	+			
Dilleniaceae					
Hibbertia crassifolia	+	+	+	+	C
Hibbertia glaberrima	+				
Hibbertia hypericoides	+	+	+	+	C
Hibbertia pilosa			+	+	C
**Hibbertia stricta*					
Droseraceae					
Drosera drummondii	+			+	
Drosera erythrorrhiza	+				
**Drosera heterophylla*					
Drosera menziesii	+	+	+	+	
**Drosera nitidula*					
Drosera paleacea	+	+	+		
**Drosera pallida*					
**Drosera sewelliae*					
Drosera stolonifera		+		+	
Epacridaceae					
Andersonia heterophylla		+			
Andersonia lehmanniana	+	+	+	+	
Astroloma microdonta				+	
Astroloma serratifolium	+	+	+		
Astroloma stomarrhena		+			
Astroloma xerophyllum		+			
Astroloma sp.	+	+	+	+	
Conostephium pendulum	+	+	+	+	C
Leucopogon conostephioides	+	+	+	+	
Leucopogon polymorphus		+			
Leucopogon striatus	+	+		+	C
Leucopogon sp. 1	+	+		+	
Lysinema ciliatum		+	+	+	C
Euphorbiaceae					
Monotaxis grandiflora	+	+	+		

Appendix 1—*continued*

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
Goodeniaceae					
Dampiera lavandulacea	+		+		
**Dampiera lindleyi*					
**Goodenia pulchella*					
**Lechenaultia biloba*					
**Lechenaultia linearoides*					
Scaevola canescens	+	+	+		
Scaevola paludosa	+		+		
**Velleia pilosella*					
Haloragaceae					
**Glischrocaryon aureum*					
Lauraceae					
Cassytha glabella				+	
**Cassytha pubescens*					
Leguminosae subfamily Mimosoideae					
Acacia auronitens	+				
**Acacia lasiocarpa*					
Acacia pulchella	+				
Acacia stenoptera	+		+	+	C
Leguminosae subfamily Papilionoideae					
Daviesia divaricata		+		+	
**Daviesia epiphylla*					
Daviesia nudiflora	+	+	+		C
Daviesia pectinata			+	+	
Daviesia pedunculata		+	+	+	C
Daviesia quadrilatera	+				
**Daviesia striata*					
**Dillwynia uncinata (patula)*					
Gastrolobium bidens			+	+	
Gastrolobium obovatum			+	+	C
Gastrolobium pauciflorum			+		
**Gastrolobium spinosum*					
Gompholobium knightianum				+	
Hovea stricta		+	+		
Isotropis cuneifolia	+				
**Jacksonia aphylla*					

Appendix 1—*continued*

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
Jacksonia floribunda	+	+		+	C
Jacksonia restioides		+	+	+	C
**Kennedia prostrata*					
Oxylobium capitatum			+	+	C
Oxylobium sp.			+		
**Pultenaea ericifolia*					
**Sphaerolobium macranthum*					
Loganiaceae					
Logania sp.			+		
Myrtaceae					
Baeckea camphorosmae			+	+	
Baeckea grandiflora			+	+	
Baeckea sp.	+		+		
Beaufortia elegans	+	+	+	+	C
**Calothamnus hirsutus (villosus)*					
Calothamnus sanguineus	+	+	+	+	C
Calothamnus torulosus		+	+	+	C
Calytrix brachyphylla	+				
Calytrix stowardii			+		
Calytrix angulata		+		+	
Calytrix sp.			+	+	C
Conothamnus trinervis	+	+	+	+	C
Darwinia speciosa	+	+	+	+	
Eremaea beaufortioides	+	+	+	+	C
Eremaea fimbriata	+	+	+	+	C
Eremaea pauciflora		+		+	
**Eucalyptus todtiana*					
Hypocalymma xanthopetalum	+	+	+	+	C
Leptospermum spinescens	+	+	+	+	C
Melaleuca trichophylla	+	+	+	+	C
**Pileanthus filifolius*					
Verticordia grandiflora			+		
Verticordia grandis	+	+	+	+	C
Verticordia ovalifolia		+		+	
Gyrostemonaceae					
Tersonia brevipes	+				C
Polygalaceae					
Comesperma sp.	+		+	+	

Appendix 1—*continued*

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
Proteaceae					
Adenanthos sp.	+				
Banksia attenuata	+	+			C
Banksia candolleana	+	+	+		C
**Banksia chamaephyton*					
Banksia leptophylla	+	+	+		C
Banksia grossa				+	C
**Conospermum incurvum*					
**Conospermum nervosum*					
Conospermum triplinervium	+	+		+	C
Dryandra aff. *falcata*			+	+	
Dryandra bipinnatifida			+	+	
Dryandra carlinioides		+	+	+	C
Dryandra nana	+		+	+	
Dryandra nivea	+	+	+	+	C
Dryandra shuttleworthiana	+	+	+	+	C
Dryandra tridentata		+		+	
Grevillea pilulifera		+			
**Grevillea shuttleworthiana*					
Grevillea synapheae			+	+	
Hakea conchifolia			+	+	
Hakea corymbosa		+			
Hakea cristata			+	+	
Hakea flabellifolia		+			
Hakea incrassata	+	+	+	+	C
**Hakea linearis*					
Hakea obliqua	+	+			C
**Hakea prostrata*					
Isopogon asper			+		
Isopogon linearis			+	+	
Lambertia multiflora		+	+	+	C
Petrophile inconspicua			+	+	C
Petrophile linearis	+	+	+	+	C
Petrophile macrostachya	+	+	+	+	C
Petrophile media	+	+	+		C
Petrophile striata			+	+	C
Stirlingia latifolia	+	+	+		C
**Stirlingia simplex*					
Synaphaea petiolaris	+	+	+	+	C
Synaphaea polymorpha		+		+	

Appendix 1—*continued*

	Sand <3yrs burnt	Sand >8yrs burnt	Laterite <3yrs burnt	Laterite >8yrs burnt	In Computer Analysis
Rhamnaceae					
**Cryptandra pungens*					
Rutaceae					
Boronia sp.				+	
Eriostemon spicatus	+			+	
Stackhousiaceae					
Stackhousia brunonis			+		
Stackhousia pubescens			+		
Sterculiaceae					
Lasiopetalum drummondii		+		+	
Thomasia grandiflora				+	
Stylidiaceae					
**Levenhookia pauciflora*					
Stylidium bulbiferum			+	+	
Stylidium crosso-cephalum	+	+			
**Stylidium hispidum*					
Stylidium piliferum	+				
**Stylidium pubigerum*					
Stylidium repens	+		+	+	
Stylidium sp.			+		
Thymelaeaceae					
**Pimelea floribunda*					
Pimelea suaveolens	+	+	+	+	
Pimelea sulphurea	+		+	+	
Tremandraceae					
Tetratheca confertifolia			+	+	C
Violaceae					
**Hybanthus calycinus*					